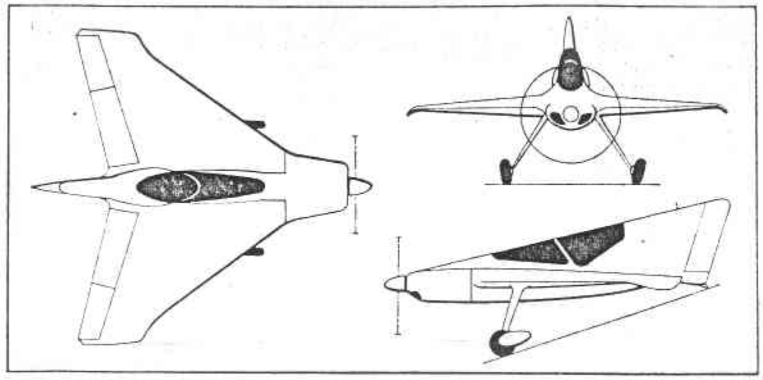
No. 93 MARCH 1994

T.W.I.T.T. NEWSLETTER

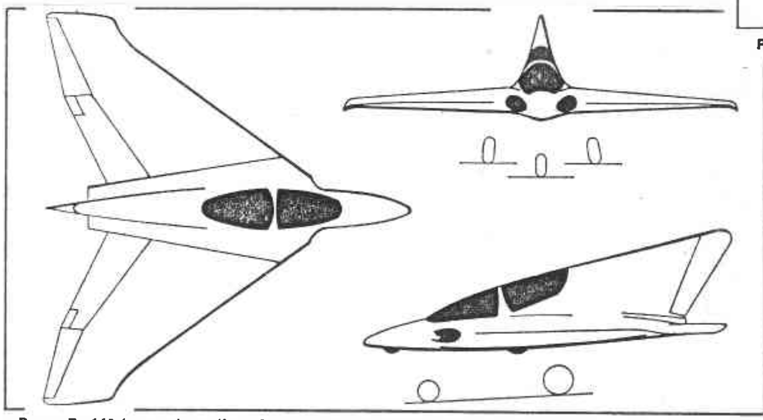
LEFT: French Pa.71 was the direct development of the Pa.49 of 1954, modified as a single-seater with a 100 hp Rolls-Royce Continental O-200 "flat-four" engine and tractor propeller for Formula 1 racing. In the initial design, the fuselage and delta wings were built integrally as a single main assembly of wood or plastic laminates.

The wing had cambered tip and was fitted with full-span ailerons and elevators. The rudder is split vertically, so that it can be opened symmetrically to each side to act an air-brake for landing, without the pitch changes that would result from the use of conventional wing flaps.

Span - 16'10"; A/R - 3; Length - 15'7"; Area - 95.8 sq'; Empty Wt - 507#; Max Wt - 848#; Max Speed - 205 mph.



Payen Pa.71 single-seat racing aircraft (100 hp Rolls-Royce Continental O-200) *(Roy J. Grainge)*



Payen Pa.149 two-seat sporting aircraft (two Turboméca Palas turbojet engines) *(Roy J. Grainge)*

RIGHT: This two-seat turbo-jet powered sporting aircraft was a development of the Payen Pa.49. The rear pilot was seated at the center of gravity which meant that no trimming was necessary when flown solo from the front. It was designed to be built up of three major assemblies, comprising the fuselage and two wings. Extensive use of laminated and sandwich plastics was intended; but much of the structure could be made by traditional wood and steel-tube construction methods. Vertical served as rudder and air-brake.

It was powered by two Turbomeca Palas turbojet engines rated at 330# thrust, with provisions for alternative Continental or Williams Research turbojets, or a single Turbomeca Marbore rated at 772-882# of thrust.

Span - 20'8"; Length - 18'8"; Area - 155-165 sq'; Empty Wt 1045#; Max Wt 1927#; Max Speed - 285 mph.

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

The number to the right of your name indicates the last issue of your current subscription, e.g., **9403** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, March 19, 1994, beginning at 1330 hrs at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - East side of Gillespie).

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis. T.W.I.T.T. is affiliated with The Hunsaker Foundation which is dedicated to furthering education and research in a variety of disciplines.

T.W.I.T.T. Officers:

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Vice Pres., Dave Pio (619) 789-1650
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Treasurer, Bob Fronius (619) 224-1497
Editor: Andy Kecskes

The **T.W.I.T.T.** office is located at Hanger A-4, Gillespie Field, El Cajon, California.

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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive, east side of Gillespie).

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PRESIDENT'S CORNER

I don't believe the response we got this month in requests for the video tape; over eight of you want them. Just to let you know, this will cause some delay in getting them to you, since it takes a little time to make each one (I don't have a high-speed duplicator). I will mail them out as they get completed, so please be patient.

For Kevin Renshaw, I apologize for your tape not having the Swift segment. I will make up another tape with it and some other material from the library, and get it off to you in the near future.

Don't forget that the March meeting will also include a special election for Vice President (see formal announcement on page 2). We would like to see a good turnout for this to show support for the winner.

Since there has been not response to our request for items we can use in a sealed-bid auction, I guess we will simply put the B-10 and U-2 plans donated by Richard Avalon up for sale at his regular asking price, $150 (OBO). These are complete with all drawings and building instructions.

Please take some time to read the Editor's column, especially the note accompanying Tasso Proppe's letter on why TWITT attendance has been declining. I really would appreciate more frank comments on what you think about the direction the organization is currently taking. Please remember that TWITT is your organization and that the Board of Directors needs your input in order to make it BETTER FOR YOU.

Since I haven't heard anything to the contrary, I assume I got all the credits assigned to the right people last month. Some of the items got mixed together, and I began to wonder if I might have stepped on some toes. If so, I apologize.

I am looking forward to this month's meeting so I can learn more about how to use all these modern construction materials in any future model I may finally get around to building.

See you all there.

Andy

MARCH 19, 1994 PROGRAM

For those of you interested in construction materials and techniques, this is the meeting for you this year. Our guest speaker will be **Alex Kozloff**, of Kozloff Enterprises, in Irvine, California.

Alex indicated he will be bringing along some samples of the types of building materials he uses, and will be explaining how to make the best use of each type. He will also talk about what is good for particular applications, and what other uses some of the materials are good for. He mentioned he would be discussing Off-axis and Carpet Plots as alternative ways of laying out some of the cloths.

If you are not into watching the television tabloid shows, then you missed a recent Inside Edition where they had a piece on paragliding. Well your ever vigilant editor managed to catch it on video, and we will be showing you this interesting footage. This is the same type of flying wing that was demonstrated at one of your meetings several years ago.

NOTICE OF SPECIAL ELECTION

On March 19, 1994, a special election will be held at the headquarters for TWITT, Hanger A-4, Gillespie Field, El Cajon, CA, for the position of Vice President, as required by Article 5, Section 7 of the Bylaws.

We currently have one nominee for the position, Bob Chase. Other nominations will be taken by mail or from the floor on the day of the election. However, the nominee must consent to accepting the position if elected.

There is a slight correction from last month's announcement, in that the vote will be conducted by written ballot, with a majority vote by the members present at the election meeting necessary elect the officer. These procedures are in accordance with Article 4, Sections 4 & 6 of the Bylaws.

EDITORIAL CORRECTION

There has been so much material presented in the newsletters over the years, I have a tendency to forget some of it. Thanks to Karl Sanders for reminding us that the Raoul Hoffman design shown on page 8 of the February 1994 newsletter was originally submitted by him and printed in the October 1992 newsletter. The source was Popular Aviation, Sept. 1935, p. 39.

In his recent letter he also pointed out that there was diagonal double wire bracing for torsional stiffeners between the spars (note the dotted lines in the top view drawing). He also mentioned another publication containing Hoffman's work; "Engineering For the Amateur Aircraft Builder," by Raoul J. Hoffman, published by the EAA Air Museum Foundation, Inc., year unknown.

FINANCIAL DATA

BALANCE SHEET (12/31/93)

Current Assets	
Cash	$ 839.05
Acct. Recvble.	202.00
Inventory	250.75
Total Current Assets	1,291.80
Fixed Assets	
Material & Equip.	2,155.25
TOTAL ASSETS	$ 3,447.05
Liabilities	
Acct. Payable	$ 1,210.75
Equity	2,236.38
TOTAL LIABILITIES & EQUITY	$ 3,447.05

INCOME STATEMENT (12/31/93)

Membership Dues	$ 1,164.00
Raffle Tickets	42.00
Back Issues	106.25
Information Packs	12.00
Donations	158.08
Miscellaneous	90.91
TOTAL INCOME	1,573.19
Less:	
Newsletter Expense	938.31
Mailing Expense	447.11
Raffle Expense	12.88
Miscellaneous Expense	484.85
TOTAL EXPENSES	(1,873.15)
NET INCOME (LOSS)	$(299.96)

(NOTE: The Net Loss for this six month period resulted from the purchase of the television set, repairs to a donated VCR, and the addition of 12 metal chairs to the organization's inventory.)

LETTERS TO THE EDITOR

2/13/94

TWITT:

You asked for comments on the question of declining membership; so here are my two cents worth of opinion.

I was drawn into the early TWITT meetings because I was one of the few people (other than Hang Gliders) that have flown tailless airplanes with a purpose (namely "soaring"), a Mitchell B10, and occasionally a Mitchell U2 (for measuring only).

I decided to build the B10 for one reason only, the kit was available and I wanted to get the engine out of my field of view. The rest was sheer curiosity; will such a contraption *soar* ??

A conventional airplane has a tail for pitch stability; the tail cost drag. So the general thinking seems to be that this drag disappears if you leave the tail off. But now, stability has to be achieved by other means; lots of, like wing sweep, twist, aileron/elevator combinations at the wing tips, computer selected span-wise airfoil distribution, all of which are cutting into the efficiency of flight performance just like the tail - and they are difficult to build. Some of the construction problems cause additional weight. Trust me, I have been there.

So, I was curious whether something develops during those meetings or in your publication, that would make me change my mind. It didn't.

My answer to your question is: if you don't physically build something that can be flown (in my case, and soared), the bystanders loose interest and peel off.

And the big "however" is: a complicated structure that would provide the stabilizing features above (sweep, twist, airfoil combinations) **cannot** be built with a group effort and insufficient tooling capabilities. It would be too time consuming anyway, and it would be overtaken by new technologies before it would fly.

I am sorry I have to be this blunt. I am maintaining my membership only for the reasons of compassion (a kind of charity) because in my lifetime (some 70 years - I am now 83), I have been an active part of many similar dreams - only a few of them turned out successes and worth the mistakes.

Good luck !

Tasso Proppe

(Ed. Note: Tasso has summed up part of the problem quite well. The difficulties in reaching a group decision on a design, plus pulling together the tooling, skills, and money to actually build an aircraft led to our current structure.

There is one other problem that I see, and that is there has been very little in the way of new ideas being presented by the membership. It appears many of the modelers want to build scale versions of past designs, while the full size members are thinking of a design but are not sharing their dreams with the rest of the membership.

Getting speakers for the bi-monthly programs has been more of a struggle in the past few years, since we are somewhat restricted to people within easy travel distance to San Diego. The subjects are also a problem, and we have only heard from a few members with suggested topics or identifying a potential speaker.

TWITT has been envisioned as a group of people with a common goal and a willingness to participate for the benefit of everyone involved. If this is no longer an appropriate description of what we are about, then we need to hear from the membership telling us what the next direction should be.

Please take some time an give us your comments. If you will do this, I will consolidate the results and report it to you when there seems to be some type of consensus.)

1/27/94

TWITT:

Please find enclosed the remainder of my yearly subscription.

As I have previously stated, I am interested in the SB-13 project and other flying wing type sailplanes like the Monarch, Pioneer, etc. I understand Peter Selinger has information on the SB-13. Could you please let me know how to contact Peter so that I may correspond with him.

I hope Serge Krauss gets his 4th edition done (hint, Serge, hint), and when you do let me know.

Looking forward to your next newsletter.

Robert Marriott
P.O. Box 194
North Strathfield
Sydney, 2137
Australia

(Ed. Note: I understand Bob has already sent you Peter's address, but just in case it didn't get to you, its: Peter Selinger, Landschreiberstr. 21, D-70619 Stuttgart-Sillenbuch, Germany.)

2/15/94

TWITT:

Here's my $8 for a copy of the video of the SWIFT and other programs.

I also have a flying wing tape which includes the history of Edwards AFB. I would like to donate it to the TWITT library if it is not already there. I'll bring it along next meeting.

Sincerely,

Chris Tuffli

(Ed. Note: Your copy of the video should be in the mail shortly. And, yes we would like to have a copy of your video for the library.

The more footage we have with flying wing material, the more we can provide to other members in future mailings.)

BITS AND PIECES

Bob Chase set us a copy of the January 1994 Aero Modeller, a British model aircraft magazine. He noted an article on the "Could Be" flying wing model, along with full size plans in the center section.

The Could Be was designed by Al Backstrom, and was inspired by a Fauvel AV-10 NoCal he did some years ago. It has a span of 25", weighs in at 43 gms, and is powered by a Brown Campus Bee CO2 motor (although other types of power could also be used).

For you modelers, if you can't find this magazine on your local book store's shelf, drop us a line, along with $1 for postage and handling, and we will send you a copy of the article and plans.

The December 1993 issue of Sailplane Builder (published by SHA) had an article by Les King, updating the progress on Don Mitchell's Stealth II project taken over by Dave Swanson.

At the time of the article, they were at the 90% complete stage, with only half still remaining. In other words, they are finishing up endless details and should start flight test soon. Initial tests will be from a truck bed test rig.

When Les spoke to our group he indicated they would let us know when some of the testing flying would be done at Torrey Pines so our members could take the opportunity to observe. This will happen during the later stages of the tests, and hopefully, it will not be too much longer before the event.

Dave and Les have plans to progress beyond Stealth II with more modern construction techniques and probably an improved airfoil section.

We will update you when more information is available.

Karl Sanders sent us a page from the February 11, 1994 issue of the Northrop News, titled "Boosters Meeting Remembers Flying Wing Programs." It is a short historical look at the development of Northrop's flying wings during a January meeting of Vintage Aircraft Boosters Club meeting. A discussion panel was made up of five men who played important parts in the design, development and flight testing of the flying wing series.

Thanks to Karl for this addition to the library.

COMMENTARY BY SERGE KRAUSS

Last month we received a letter from Serge Krauss in response to requests for comments on a variety of subjects in several of the newsletters.

In publishing his cover letter and the postscript from the following letter, we indicated it would be published in its entirety this month. Pages 5-10 are his letter in its original (corrected) form for your enjoyment and consideration.

We hope everyone finds something of interest in it, and that perhaps it will stir up some further discussions, analyses, and/or spur someone into looking at new designs. Please feel free to write us with your comments or observations so that others may benefit.

AVAILABLE PLANS & REFERENCE MATERIAL

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by Serge Krauss

3rd Edition: An extensive collection of books, articles and other items related to the development of flying wing (tailless) aircraft design and construction.

Cost: $20
Order from: Serge Krauss
3114 Edgehill Road
Cleveland Hts., OH 44118

Tailless Tale, by Dr. Ing. Ferdinando Gale'

Consists of 268 pages filled with line drawings, tables and a corresponding English text. It is directed towards modelers, but contains information suitable for amateur full size builders. Price is $38, postage and handling included (also applies to Canada and Mexico).

You might also want to purchase his new book **Structural Dimensioning of Radioguided Aeromodels**, priced at $18.00.

On The Wing...the book, by Bill and Bunny Kuhlman (B^2) is a compilation of their monthly column that appears in RCSD. Many of the areas have been expanded and it includes coding for several computer programs to determine twist and stability. Priced at US$28.00.

(continued on page 11)

November -December, 1993

T.W.I.T.T.
P.O. Box 20430
El Cajon, CA 92021

Dear Andy,

The November newsletter invites a variety of comment, but I had no idea how one thing would lead to another! Not only did I miss the December deadline, but now a short note has grown to gargantuan proportions; use what you like.

Yes, the passing of Jerry Blumenthal, who must surely have personified the spirit of T.W.I.T.T., and major figures like Dr. Horten and Don Mitchell, contribute to what seems a dark year indeed! I fear that we have not seen the end of the current loss of creative lives. Still, there is inspired thinking going on; progress among our somewhat nebulous tailless aircraft fraternity is a source of satisfaction and increasing interest. As Don Mitchell's work is ably carried on and the SWIFT becomes available, the Marske camp may soon give us further cause for celebration; the wing is hitting the major press again. In the midst of all this, Edwin Sward (Nov.) opens discussion of an unlikely use for my favorites, the low A/R tailless aircraft. Where to start...?!

Milt Hatfield

First, a note of some regret, but potential interest to fellow TWITT's: in researching a response to Edwin Sward's letter, I contacted Milt Hatfield concerning his experience with the low-A/R Snyder Arups of the '30's and his own Arup derivative "Little Bird". After some sixty years in the air and designing and building a variety of fascinating planes, Milt has had to call it quits, ill health rendering even design work extremely difficult. He last flew the "Little Bird" over a year ago, having perfected the design and produced kit-part molds. He now wants a buyer for the molds, plans, and production prototype - a business set-up he considers profitable. The "Little Bird I" (ultralight) was featured in Sport Aviation (3/87), and Aeroplane Monthly (9/87), while "Little Bird II" (refined and heavier than the ultralight limit) appeared in Kitplanes of 2/90. The "Little Bird II" weighs 312 lb. empty, spans 19 ft., and is only 12 feet long. With a 40-hp Rotax 447, it takes off or lands in 150 ft., climbs 600 ft/min, cruises at 70 mph., mushes (its version of a stall) at 24 mph, and can land quite steeply and slowly, with no flaps - a real short-field tailless. Milt describes the production prototype (L.B.3: 262 lbs. empty, 26 h.p.): "beautiful...flies great!". I believe TWITT has mentioned having a videotape featuring films of the Arup S-4 at South Bend in 1933 and Hatfield's first flights in LB's 1 and 2. Hatfield's plane flies well with NO horizontal helping surfaces; except for its vertical stabilizer, it's really tailless. Anyone interested in marketing a great little tailless plane can contact him at (219) 293-0937.

Jim Marske: Group Genesis

Peter King's letter in the November issue appeared at an apt time, since I had just the previous week visited Jim Marske at his new headquarters in Marion, Ohio (with and at the instigation of Bill Foshag). Long familiar with Marske's Pioneer and Monarch sailplanes through the normal literature and his informative 1970 booklet, *Experiment in Flying Wing Sailplanes*, I found it a real treat to talk at length with him and see the progress of his current enterprise with John Roncz and Jerry Mercer. Kindly, easily approachable, and willing to share what he knows, Jim offered fascinating insights into the development of Genesis I. 'hope some of this is of interest.

The Wing IS The Thing for Genesis I. Marske has waited years for wing sections which would enable him to produce a world class soarer and, with the help of a suitably enthusiastic Roncz, now seems to have them. I found his description of airfoil progress fascinating. His original experience was with a 17% Fauvel section giving an infinite-A/R L/D_{Max} of 67:1 ($C_{L\,Max}$ = .8). Thinned to 14% for the XM-1 sailplane, the L/D_{Max} went to 80:1. He then used a reflexed NACA 33012 section, achieving 100:1. In search of world-class performance, he tried a German HQ section used on the SB-13 sailplane, finding its L/D_{Max} to be 125:1, with a claimed $C_{L\,Max}$ of 1.3. He thinned this to 12%, raising the L/D to 135:1. He discovered that values as high as 150:1 could be achieved on such reflexed sections, but with a uselessly small low-drag "bucket" and $C_{L\,Max}$ of 1.1. He turned the work over to Roncz at a L/D of about 137:1, but insufficient $C_{L\,Max}$. By thickening the section and making modifications that ARE extremely proprietary, John has raised the L/D_{Max} to 143:1, with a $C_{L\,Max}$ of 1.22. These reflexed sections maintain laminar flow, where desired, over 62% of the chord. It is not clear to me whether John's current section is entirely new or a derivative of the HQ's.

With such sections come inherent design constraints. The result is a striking ship, with significant forward sweep and twist and a horizontal "trimmer" at the tip trailing edge of its long, high-A/R, swept vertical stabilizer. It is designed for the standard class. Final configuration and placement of elements is to a great extent computer generated, the principals having concluded computer simulation to be superior now to wind tunnel work. So far the program has shown large savings in drag to be possible with minute changes in wing root position, preventing the tripping of laminar flow over significant fuselage areas. With each half pound of drag reducing the L/D by about one point, subtle changes cause large effects in the low-drag realm! The configuration is dictated among other things by the need to preserve the most advantageous lift distribution.

Jim would like to have built the plane completely tailless and speaks enthusiastically, if not hopefully, of following up with a fully tailless version for direct comparisons. Elimination of the trimmer as a source of drag, allowing a shorter fuselage with less wetted area, better fineness ratio, and lower moment of inertia, might offset disadvantages of the configuration change. He's also concerned about the amount of twist specified, but feels that they have that variable covered through adjustability allowed by properties of their structural materials.

Computer simulation ranges from exquisite mappings of pressure distribution over the entire ship to relative performances of Genesis and its European competition "flying" head-to-head over known contest courses. The Computer has shown a steady improvement in L/D over the course of development, now predicting a L/D_{Max} of 43-46:1 and superiority over standard class competition in significant areas. Group Genesis hopes to challenge the Europeans in the market and to be competitive in contests next summer.

At present, the prototype's upper and lower wing skins and attached composite spars are out of the molds, controls are being installed, and fuselage modifications seem about at an end. Wing tips are to be configured by each builder to his own preferences. The FAA's 51% rule or its equivalent is a concern, since accuracy in construction of the complex wing is critical. Testing should commence locally very early in 1994.

On other fronts, Jim is tinkering with his other aircraft, when time permits, but this is the one area in which he asked me not to discuss specifics. He has also completed new Pioneer drawings for use if the opportunity arises. The Monarch stayed up for 8 1/2 hours on 7/15/93 near Elmira - a new national, and probably world, ultralight sailplane class record. Just recently it made some skeptics into believers at the local airport, where it stayed up for some hours while conventional sailplanes failed to find sufficient lift.

Equations

The accompanying page of equations was derived with a little algebra and freshman calculus from standard textbook fare to satisfy my curiosity about L/D, sink rates, and speeds of gliders. Since, aside from number (1) (Milliken), they weren't to be found in any of my old textbooks, I thought they might appeal to readers interested in roughing out tailless sailplane designs. They seem to give reasonable and consistent results, but you might run them by Bruce Carmichael (who told me where to start) to make sure I haven't screwed up anywhere. According to the lifting-line based equations, aspect ratio and drag coefficient are the prime determiners of (L/D)max, but span loading dominates equations for sink rate and the speeds at which (L/D)max and (Vz)min occur. Even for low-A/R wings, they show the approximate relative effects of changes made to various parameters. The cumbersome Weinig equations are two of several from a 1942 German article translated as NACA TM No. 1151 and giving a modified lifting-line theory to accomodate low A/R wings. (L/D)max occurs at angle giving $C_{Di} = C_{Do}$. These might form the basis of a simple spreadsheet to explore sailplane gliding performance.

A word of caution: failing to account for the effects of vortex interaction and shape on narrow wings, the textbook-derived equations are inaccurate regarding lift and drag coefficients for low A/R aircraft (although equation (1) seems only slightly conservative in predicting (L/D)max). Coefficients in the sea speed equations reflect sea level air density only. The Weinig equations accurately mirror Zimmerman's results for rounded wings at low angles of attack (near L/D max; a = 3.5^0 = .061 radians), but miss the C_L max by 100% at a = 45^0! Not ideal, but I still had an interesting time exploring the low A/R realm with these equations. You just have to explore the equations themselves by comparing to known data.

Low Aspect Ratio

Edwin Sward's letter (Nov.) on circular wings led me to explore the potential of circular, annular, and other low-aspect-ratio gliders (A/R $\leq$ 2.0), an area universally neglected due to their known shortcomings in glide. A few evenings of derivations, number crunching, and mathematical "archaeology" (including exploring the limits of standard equations at low A/R) resulted in tentative performance expectations sufficient to delineate a role for such aircraft. Despite questioning the "low and slow" description ('steep and fast' is better), I agree that there may be a place for them in recreational or even competition gliding (of a different kind). To be much more than "umbrellas" though, they must be clean. Span^2/Area-limited events can embrace the peculiarities of low-A/R tailless planes and produce new knowledge.

GENERAL CONSIDERATIONS: Due to lower lift coefficient curve slopes, low-A/R wings (annular or otherwise) achieve lift comparable to conventional aircraft only at higher attack angles (incurring higher drag) or at higher speeds. The induced drag penalty is considerable, but less than predicted by standard lifting-line theory, due to recovery of some vortex energy, which allows them to fly at higher than predicted lift coefficients for a given angle of attack and (for A/R < 1.5) to maintain lift at angles of attack well past the normal stall. This gives Low-A/R aircraft a high ratio of maximum to minimum flying speeds, possibly allowing gliders as well as powered planes to land very slowly, without flaps. Large chords also provide some advantage in profile drag coefficient due to higher Reynolds numbers. L/D is at best modest.

ANNULAR PLANFORMS: Difficult to analyze, 3-D flow makes them more than low-A/R wings w/holes or joined-wing tandems. They should be less severely handicapped by induced drag than Snyder or Zimmerman types, depending on relative size of the opening. Vortices appear at inner and outer edges of the annulus, augmenting lift and delaying stall. They tend toward longitudinal stablity. C_L max can be above 1.8.

Sparse info. from historical references leads to extremely coarse guestimates of L/D. The "always over 1 in 8" glide angle claimed by Lee and Richards for their open, manned, 22 ft. span, semi-biplane annular glider of 1912 yields C_{Do} of .049 and an effective aspect ratio of 4.0 (although b^2/A = 1.73). Standard equations then project (L/D)max's of 16.2 for C_{Do} = .012 and over 20 for laminar figures. These values should be higher with reasonable Reynolds numbers. In contrast, the Lee-Richards No.2 monoplane showed standard-equation (L/D)max values of only 5.9-8.7 - engine, landing gear, and all - depending on what you think the effective A/R is (!). These extrapolate to 10.6-16.2 at C_{Do} = .012. The lift curve slope for the Warren-Young "sky car" gives an effective A/R even less than its geometric A/R and similarly intermediate L/D values. It seems that the best non-laminar L/D falls somewhere between 10 and 17 for similarly proportioned planes. How does one mathematically model an annular wing? What IS its effective A/R? I would really like to hear what our experienced aerodynamicists have to say about this! Would an R/C soaring member care to build and test a clean, 1/4-scale annular slope soarer? B^2?

LOW-A/R, ROUNDED TAILLESS: The following theoretical values for (L/D)max were calculated using the Weinig low-A/R equations of NACA TM 1151 and are closely mirrored by Zimmerman's research (TR No.431 and TN No.539) and the standard textbook equation:

(L/D)max for Various Minimum Drag Coefficients

$C_{D\,min}$:	.0045	.0075	.010	.012	.015	.0173	.020	.040
A/R=1.27	14.9	11.4	10.25	9.4	8.4	7.9	7.3	5.26
A/R=2.0	18.9	14.7	12.8	11.7	10.5	9.8	9.1	6.5
	laminar wing-only	laminar aircraft	non-laminar wing-only	"clean" aircraft				

To put these figures in context, the following (L/D)max's were found in reports, calculated theoretically, or extrapolated from flight data:

Observed and Measured Data

(1) Circular Clark Y, wing-alone at R_N = 860,000, A/R = 1.27 (Zimmerman: NACA TR 431 and TN 539, 1932): (L/D)max = 9-10; Projected for high R_N: 10-11.
(2) Full-scale Zimmerman/Vought V-173 (A/R=1.27; tunnel wall interference): (L/D)max = 10.2 at 5^0-9^0.
(3) Snyder Arups (A/R = 1.7-1.8) and Hatfield "Little Bird" (A/R = 2) with exposed gear and prop windmilling: glide ratio reportedly approx. 4.
(4) Snyder's manned "Dirigiplane" glider (Arup S-1, A/R=1.7): glide ratio claimed 12.
(5) Turin wind tunnel tests of Canova models (A/R = 2-2.05): L/D max = 9.0 - 11.4.

L/D calculated from flight data

	L/D at Vmax or Vcr (L/D = WV/P)	(L/D)max (Std/Weinig)	(L/D)max at C_{Do}=.012 (Weinig)
R. Hoffmann (A/R = 2.17):	5.98	10.5	12.2
"Little Bird's" 1-3 (A/R = 2-2.3):	3.8 - 4.3	5.3 - 6.5	11.7 - 12.5
Arup S-2, S-4 (A/R = 1.71, 1.77):	5.0 - 5.9	7.2 - 9.0	10.8 - 11.0
V-173 (A/R = 1.273):	6.1 - 8.2	8.4 - 9.3	9.4 (see above)
XF5U-1 (predicted; A/R = 1.273):	5.2 - 6.0	7.9 - 9.2	9.4
R.B. Johnson Uniplane (A/R = 1.07):	3.38*	3.8*	8.6
Moskalyev SAM-9 (A/R = .945):	2.7	6.9	8.0

* Inaccuracies may have resulted from overly optimistic power figures.

Notes: Weinig (L/D)max values fall .26-.3 higher than standard values in the range studied, corresponding to a roughly 5-6% increase in the effective A/R. Weinig computations also show a higher C_L for a given angle of attack. For low parasite drag coefficients, small drag changes yield large losses or gains in (L/D)max.

Overall, higher Reynolds numbers, smoother composite surfaces, and absence of draggy engines, props, and landing gear ease the pain some, but the numbers don't look realistic for normal sport gliding - especially hang gliding, since Rogallos (L/D = 4) were simpler and cheaper. Best L/D expected is 9-12 without laminar flow and 11-15 with it. Open (draggy) designs would probably have L/D's of 4-7. The best L/D's (A/R near 2.0) sacrifice high-attack-angle stall resistance, but ground effect is still a factor in landings. Heavy influence of span loading allows sink rate to be diminished through weight reduction, but span dominates equation: some duration possible. Cross country looks out of the question, as do MPA's out of ground effect. However, high Vmax/Vmin ratios may make otherwise "outrageous" closed-course events just viable.

COMPETITIONS FOR $SPAN^2$/AREA-LIMITED AIRCRAFT: Without pretense of expertise in this area, I'll suggest that beautiful and appealing aircraft seem possible in a 12'-20'span, low-A/R glider category and that events appealing to the designer/builder - or even the daring - are not necessarily a bad thing. Low-A/R idiosyncracies might even be advantageous if appropriate events were created. Would it be realistic to consider "downhill" events, with emphasis on speed - fast AND slow, maneuverability, or range? From L/D contenders to fast downhill "skimmers", a variety of exciting aircraft might challenge the idealist. Slope would have to exceed glide slopes, but launches could be by any method from foot, through catapult, to tow, and pilots might even "pull up" to slow, bird-like landings after each run. Events in updrafts along slopes might still be possible for aerodynamically clean types. Rules stipulating minimum area and maximum weight could keep out the Kamikazes. Whether or not such activities would be palatable to current soaring fraternity, imaginative configurations and new knowledge should result. It's certainly a different challenge. Racing anyone?

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P.S. I've noticed that much early data seems conservative in its performance figures, probably because it was done at low Reynolds numbers. For comparison, Marske says that his Eppler program shows a 70% increase in L/D for an increase in R_N from 500,000 to 2 million and 100% for 3 million. While this laminar stuff is impressive beyond anything I'd heard before, even my older literature (Diehl) shows reductions of 15%-30% in profile drag when going from 500,000 to 7,000,000, a significant boost to (L/D)max in low-A/R wings. Would any of the resident aerodynamicists care to clarify just how much aircraft performance (profile drag or L/D) is affected by R_N? Meeting discussion topic?

Equations Useful in Performance Estimates ~ S. Krauss

I Lifting-line Eqns ~ derived & from Std. texts: (inaccurate for very low AR)

1) $$\left(\frac{L}{D}\right)_{max} = \frac{\sqrt{\pi}}{2}\sqrt{\frac{AR\,e}{C_{D_0}}}$$ (milliken) $\left(= \tan\left[\cos^{-1}\frac{V_z}{V}\right]\right)$

2) Speed at $(L/D)_{max}$: $$V_{(L/D)max} = 21.7832\sqrt{\frac{W}{b^2}}\sqrt[4]{\frac{AR}{C_{D_0}}} = \frac{45.017}{\sqrt[4]{C_{D_0}}}\sqrt{\frac{W}{b^2}}\sqrt[4]{\frac{a_0 a}{a_0 - a}}$$ – (α in degrees)

$$= \frac{21.7832\sqrt{W/A}}{\sqrt[4]{C_{D_0}AR}} = \frac{21.7832\sqrt{W}}{\sqrt[4]{C_{D_0}}\sqrt[4]{A}\sqrt{b}}$$

3) Sinking speed at $(L/D)_{max}$: $$V_z \approx 24.5764\sqrt{\frac{W}{b^2}}\sqrt[4]{\frac{C_{D_0}}{AR}}$$ (approximation for $C_{D_0} << AR$)

$$= \frac{43.566\sqrt{W/b^2}\,\sqrt[4]{C_{D_0}AR}}{\sqrt{4C_{D_0} + \pi AR}}$$ (actual)

4) Sink Rate: $$V_z = \frac{2W}{\rho\pi A\,AR\,V} + \frac{\rho A C_{D_0} V^3}{2W} = \frac{267.71\,W}{A\,AR\,V} + \frac{.001189\,A C_{D_0} V^3}{W} = \frac{267.71}{V}\left(\frac{W}{b^2}\right) + \underbrace{\frac{.001189\,C_{D_0}V^3}{(W/A)}}_{small}$$

5) minimum Sink Rate: $$V_{z_{min}} = 21.57\sqrt{\frac{W}{b^2}}\sqrt[4]{\frac{C_{D_0}}{AR}} = 21.57\sqrt{\frac{W}{A}}\sqrt[4]{\frac{C_{D_0}}{AR^3}}$$

6) Speed at min. Sink Rate: $$V = 16.55\sqrt{\frac{W}{b^2}}\sqrt[4]{\frac{AR}{C_{D_0}}} = \frac{16.55\sqrt{W/A}}{\sqrt[4]{C_{D_0}AR}} = \frac{.8071\sqrt{\frac{W}{A}}}{\sqrt{\rho}\,\sqrt[4]{C_{D_0}AR}}$$

7) (L/D) at min. Sink: $$\left(L/D\right)_{min V_z} = \tan\left\{\cos^{-1}\left[1.3\sqrt{\frac{C_{D_0}}{AR}}\right]\right\}$$

$$= \left\{.5887\frac{AR}{C_{D_0}} - 1\right\}^{1/2} = \sqrt{.5887\frac{AR}{C_{D_0}} - 1}$$

$$\approx \sqrt{.5887\frac{AR}{C_{D_0}}}$$ for $AR >> C_{D_0}$

8) From (2) & (6): $\frac{V(max\,L/D)}{V(min.\,sink)} = \underline{1.316}$

9) From (3) & (5): $\frac{V_z(L/D\,max)}{V_z(min)} \approx \underline{1.14}$ $(AR >> C_{D_0})$

10) From (1) & (7): $\frac{(L/D)max}{(L/D)\,min\,sink} \approx \underline{1.155}$ $(AR >> C_{D_0})$

II Weinig (1942) ~ intended for low AR applications:

$$C_L = 2\pi\,\frac{\tan\left(\frac{1}{AR/2 + \frac{2}{\pi}\sin\alpha}\right)}{1 + \tan\left(\frac{1}{\frac{AR}{2} + \frac{2}{\pi}\sin\alpha}\right)}\left(\frac{AR}{2} + \frac{2}{\pi}\sin\alpha\right)\tan\alpha$$

Note: α in radians!

$$C_{D_i} = 2\pi\left(\frac{\tan\left(\frac{1}{\frac{AR}{2} + \frac{2}{\pi}\sin\alpha}\right)}{1 + \tan\left(\frac{1}{\frac{AR}{2} + \frac{2}{\pi}\sin\alpha}\right)}\right)^2\left(\frac{AR}{2} + \frac{2}{\pi}\sin\alpha\right)\tan^2\alpha = \frac{C_L^2}{\pi AR + 4\sin\alpha}$$

b = span
A = area
AR = aspect ratio = b^2/A
V = speed
W = weight
α = angle of attack (in radians)
ρ = air density = .002378 (Std.)

a = C_L Curve slope
a_0 = C_L Curve slope for AR = ∞
C_L = Lift Coefficient
C_{D_i} = Induced Drag Coeff.
C_{D_0} = Zero-lift Drag Coeff.
e: subscript "effective"

Numerical Coefficients set for use of std. English System units: lb, ft, sec. V in ft/sec